PRESENT STATUS OF THE PANAMA PROJECT

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To form an intelligent appreciation of the present status of the work upon the Isthmus one must understand the physical conditions there existing, the character of the project adopted for the canal, the organization under which the work is now in progress, and what has been accomplished. Each will be considered in turn.

When the concessions and property were transferred by the New French Company to the United States, on May 4, 1904, it was unavoidable, before serious work of construction could be inaugurated, that much preparatory work should be undertaken, and that a definite project for the canal should be elaborated and approved by Congress—which latter was not done until June 29, 1906. The actual period of preparation has covered about three years, and it would be easy to show that in general the time has been well spent; but the details of what has been done in advance of the adoption of the final project pertain rather to history than to the present inquiry. It suffices to state that the cities of Panama and Colon, and the Zone itself, have been supplied with potable water and placed in a sanitary condition entirely satisfactory; that the requisite engineering plant and a large force of laborers, some 30,000 men on the canal and railroad, with comfortable quarters and good arrangements for messing have been provided; that much of the Panama Railroad has been double-tracked, and its yards, docks and other facilities largely extended; and, finally, that at the end of March, 1907, when the present canal organization was inaugurated, nearly six million cubic yards had been excavated from the great Culebra cut at an average cost of about 78 cents per yard; about three and a half millions had been dredged, and work on the locks and dams was beginning. Such, in brief, was the status early in the current year. It remains to consider the elements of the problem as now presented.

Physical Conditions on the Isthmus.

There are no mountains properly so called on the general line of the canal; indeed the highest summits of the continental divide in this district hardly exceed 1,500 feet above tide, while at the Culebra where the route crosses it, and where much work has been done already, the original level did not exceed about 345 feet, now reduced to 312 feet by a slight change in line. For about seventeen miles between Bohio and Empire, igneous rock in the form of brechias, or conglomerates, or massive overflows known locally as the rock of Gamboa, lies at or near the surface; but on both the Atlantic and Pacific slopes it is overlain by ancient sedimentary formations of the tertiary period, composed of much softer materials but occasionally traversed by igneous veins. Nearer the coasts ancient and modern alluvial deposits occur. The deep cut between Bas Obispo and the southern terminus of the Culebra lies chiefly in the softer material; its total length hardly exceeds seven miles, and only about one mile of it is really of a formidable character by reason of its height.

Much has been said about danger to the canal from earthquakes, which are popularly supposed to be frequent throughout all Central America. Fortunately the long chains of volcanoes approaching from the north and from the south both deflect to the eastward before reaching the Canal Zone, to appear in the Lesser Antilles. The Republic of Panama lies near the middle of a quiet district between Chiriqui and Tolima, some six hundred miles apart, where no volcanic eruption has occurred since the miocene tertiary, and where such earth movements as do occur are those transmitted with lessened intensity from distant foci of disturbance. Since the foundation of the old city of Panama, in August, 1519, only two earthquakes classed as severe are of record; but one of them, in 1621, is considered as doubtful by M. de Montessus after a discussion of the ancient documents, and in this opinion he is supported by recent local studies. The other, occurring on September 7, 1882, coincided in time with a violent earthquake at Sucia, on the Atrato River, about fifty miles from the Atlantic. It caused some unimportant damage at Panama and on the line of the railroad, but the fact that it did not rupture the exceptionally flat arches of the ruins of the old Santo Domingo Church, burned in March, 1756, demonstrates that no serious injury would have been

done to the massive constructions of the projected canal. These views as to the comparative immunity of the route are supported by recent direct observations covering forty months. Delicate seismographs were established at Panama; and the records, compared with those kept simultaneously at San Jose de Costa Rica under governmental control, showed only four light shocks, as against ninety-one light and thirty-five strong shocks. No route between the oceans—indeed no point on the earth's surface—is wholly exempt from such dangers, but the canal follows the line where exemption seems most probable.

The chief technical difficulty is presented by the Chagres River, whose banks must be closely followed between Gatun and Gamboa, a distance more than half that between the oceans. This turbulent neighbor gives rise to more complex problems than the passage of the mountain ranges which barred the routes of our Pacific railroads,—any engineering project must be adjusted to the terrain, and here the river dominates.

The stream is a typical torrent of the tropics, characterized in nine months of the year by violent freshets, which sometimes, but rarely, develop into destructive floods, inundating the entire valley. The volume at Gamboa may then attain 80,000 feet-seconds; at Bohio, 115,000 feet-seconds; and at Gatun probably 160,000 feet-seconds,—nearly that of the Potomac at Great Falls, Md. If overgenerous in the rainy season, the Chagres becomes niggardly in the three dry months, when its flow, largely supplied by ground water, is insufficient to operate a canal with locks. With them storage reservoirs are a necessity. The river has another peculiarity which aggravates the difficulty of its regulation, especially if a sea level solution be contemplated. At Bohio, some twenty-seven miles above the mouth by the course of the stream, the water surface at the extreme low stage is only about a foot above the level of mean tide on the Atlantic coast, where the tidal oscillation is about a foot and a half. Small as this variation is, it causes at such times a three-inch tide at Bohio. But the most important effect of the deficient slope of the bed below that point is to cause a piling up of the water in times of flood, resulting in a maximum rise of some forty feet, which exceeds that at any other point of its entire course and considerably aggravates the problem of regulation unless (as has been done) the dam site be chosen lower on the stream.

The annual flow of the Chagres and its distribution throughout

the different months have important bearings upon the canal problem, and they are now well understood. Daily measurements for seventeen years (fourteen by French and three by American engineers) have been made at Bohio, where the drainage of about 700 square miles passes the station. The average monthly volume during this period is 4,587 cubic feet per second, distributed in the different months in the following percentages of total annual flow. For comparison with streams in the northeastern part of the United States, similar estimates are quoted from "Water Power," by J. P. Frizell, third edition, published in 1906. In the Chagres, although rainfall is the primary cause, ground water has much to do with the progressive changes in volume from month to month, as will appear below:

Percentage of Annual Flow (55,044 Feet-Seconds).

	The Chagres	Northeastern U. S.		The Chagres.	Northeastern U. S.
January	7.0	10	July	9.6	2
February	2.7	14	August	10.7	3
March	1.8	20	September	10.5	3
April	2.6	15	October	12.3	5
May	7.2	.10	November	15.2	6
June	7.1	4	December	13.3	8

The sedimentary matter carried by the Chagres varies considerably, being of little importance at low stages, but increasing in freshets and floods. The material is so fine that no delta has been formed at the mouth, but it cannot be ignored in a project for the canal. Sand bars exist, especially in the upper river, where the frequent variations in discharge and the rapid slope of the bed produce a very unusual phenomenon—a complete sorting of the material, some bars consisting of fine sand, others of large pebbles, and others of rocks as large as one's fist. The latter probably move only in the great floods when the absorption of the fall existing in the numerous rapids gives a general quasi-uniform slope to the water surface capable of causing extraordinary velocities.

It is manifest that such a river demands the closest study in order to accommodate the canal in the best possible way to its vagaries. This it has received for many years from the engineers of the French administration, and researches are actively continued

at the present time. All recent results confirm the older conclusions. One of them of a general character is important as bearing on the work of construction. Both the measured monthly discharges and the recorded frequency and heights of the freshets concur in indicating that alternate epochs of large discharge and of small discharge succeed each other at considerable intervals, and that one of the latter is now and has been passing for some ten or eleven years. The last maximum epoch, the first since the construction of the Panama Railroad, occurred during and probably just before the operations of the de Lesseps Company (1881-88); and it should occasion no surprise if its successor should soon make its appearance.

One most fortunate event occurred in last December in the form of an exceptionally large flood, the first since 1893. It had been eagerly awaited for long years by the engineers of the canal; because the standard flood, upon which the hydraulic problem of regulation had been solved, occurred in 1879, before systematic gauging had begun, and its estimated volume had been based upon the known maximum heights attained at a few points, and upon the study of smaller floods measured subsequently. Verification of the estimates as to volume and duration was earnestly desired. The opportunity was afforded by the records secured by Mr. Arango during the flood of 1906. The level attained at Gamboa was only one foot, and at Bohio only seven-tenths foot below the standard flood, and the duration of the dangerous period was several hours less than had been assumed for 1879. The maximum volume fell below the estimated standard by only about 2,600 feet-seconds at Gamboa and 4,700 at Bohio. The previsions of the engineers, which had been claimed by some to be excessive, were thus amply justified.

This recent flood largely exceeded any other which has occurred in the past half century, except that of 1879. The rainfall at its height, following two weeks of heavy downpours, registered about four inches in twenty-four hours. About fifteen miles of the main line of the Panama Railroad were submerged from two to ten feet, the water standing on the track at Matachin five feet deep; two small bridges were carried away and other damages were reported. The material losses in 1879, enhanced at Colon by a destructive tempest from the north, were much larger.

Another feature of this interesting river has been developed by researches covering about nine years, six under French and three under American direction, and both are perfectly in accord. They were designed to check the conclusions based on geologic examination that no serious percolations are to be apprehended from the artificial lakes to be created for the regulation of the Chagres. The climate of the Isthmus, where frost is unknown and where the regular succession of wet and dry months facilitates the study of rainfall and outflow, has been of great assistance. The result demonstrates that the river traversing a densely-wooded region receives large contributions from ground water, in fact fully one-third of the annual rainfall, and hence that no important subterranean outlets can exist for the escape of the canal reserves. This ground water flow amounts to little or nothing in May, at the end of the dry season, but then gradually and uniformly increases until a maximum is reached in November, after which the rains soon begin to diminish, and in February, March and April the stream is fed almost wholly by ground water. The subterranean flow is thus regulated by the successive filling and emptying of a great reservoir formed by the soil, which has little or no outlet but the bed of the stream. Space is lacking here for the details of these researches, but the practical conclusions admit of no doubt.

The climate of the Isthmus is another element which cannot be ignored in considering the problems of the canal. The temperature from month to month hardly varies throughout the year, the annual mean in the shade being about 80° F. The daily range in the interior in the dry months differs but little from 73° F. at 6 a. m. to 89° F. at 1 p. m.; and in the rainy season from 75° F. at 6 a. m. to 86° F. at noon. On the Pacific coast extremes occur a little later, and the range is some 3° less. The mercury when directly exposed to the sun's rays rises, of course, much higher; at Empire the records show an average of about 106° F. in the months when the sun is far to the southward, and 122° F., or even more, for the months when it is more nearly overhead at noon. Humidity is always excessive, ranging between about 0.80 in the dry months to about 0.87 in the rainy. The uniformity of barometric readings is even more remarkable. During five continuous years at Alhajuela the extreme variation was only 0.44 inch; and at Ancon in 1906 it was only 0.28 inch. Uniformity of high temperature and

excessive humidity are the governing characteristics of the atmosphere, and this, with persons of northern birth, produces lassitude and need of occasional change; but on the other hand the absence of frost will greatly assist the making of concrete for locks, and their practical operation in the passage of ships.

The winds of the Isthmus are usually gentle, ranging from five to eight miles per hour on the Caribbean coast and about the same on the Bay of Panama. There is a noteworthy absence of the hurricanes so common in the West Indies, which here are represented only by what are called "northers" at Colon, occurring at rare intervals, but dangerous at such times to shipping lying at the piers. In the interior very little annoyance from winds will be experienced by vessels in transit.

Rainfall here is more subject to known laws than in temperate regions, being regulated by the annual movement of the sun in declination carrying with it the axis of ascending moist air to be condensed by cold in the upper regions and precipitated in the form of a rain belt oscillating north and south following the sun. In the Canal Zone, lying in latitude 9° north, the sun is at the zenith on April 13, moving northward, and again on August 29, returning southward. This naturally divides the year into dry and rainy seasons, sharply defined. The former extends approximately from the middle of January to the middle of April, the rain belt being then to the south. At this time in the interior, where the heaviest work is required, the monthly downfall averages about one inch, falling in about seven days. The rainy season covers the rest of the year, with a monthly downfall averaging about twelve inches falling in about twenty-one days, but on many of these days the showers are light. Near the Atlantic coast the annual precipitation is about 140 inches, while near the Pacific it is only about sixty inches. In the interior it ranges from place to place between these limits. Experience has shown that this heavy downfall practically reduces excavation output in the rainy season not far from twenty-five per cent, largely by reason of increased difficulty in shifting track and transporting material to the dumps.

The health conditions on the Isthmus are no longer what they were during the construction of the Panama Railroad and the tentative operations of the de Lesseps company. Colonel Gorgas, by practically applying modern sanitary methods, has brought about a

marvelous improvement, and residence in the Zone is now hardly more dangerous than in many localities in the United States. Formerly the yellow fever caused many deaths, although in nowise endemic, as was proved by prolonged disappearances. As in our southern states, it took the form of epidemics caused by importations. The last one occurred in 1905, but was soon suppressed, no case appearing after May, 1906. Out of a total population of 108,206 persons in the Zone and the cities of Panama and Colon in September, 1907, only 297 deaths from all causes occurred, showing an annual average per 1,000 of 32.93. For the employees of the canal and railroad the corresponding figures in this month were 41,062, and 98, and 28.63. Under the efficient administration of Colonel Gorgas the dreaded tropical diseases of the Isthmus have lost their terrors.

Project Adopted for the Waterway.

It is known to every one that for long years a struggle was in progress in the United States, first as to the route and later as to the type of construction. Both questions have been happily settled, and it is only needful at the present time to consider the project formally adopted by the government.

The line followed by the canal measures about 40 miles between shore lines, and 49.35 miles between 41-foot contours in the Bay of Limon and the Bay of Panama. Both ports have met the demands of commerce since the earliest dates, and no engineering difficulty will be experienced in adapting them to the largest class of modern shipping. It is well to remember in what follows that the general direction of the route is from northwest to southeast, Panama lying some twenty miles to the eastward from Colon.

At Gatun, three miles from the shore of the Bay of Limon, the canal reaches the Chagres River. Here will be constructed three duplicate locks, with lifts of 29 feet, and a dam to create a lake having 165 square miles of surface and rising 85 feet above mean tide level (which is the same in both Limon and Panama Bays). This great lake forms the summit level of the canal. Its depth on the ship route will be never less than 42 feet, and for sixteen miles its navigable width will generally exceed half a mile. In the next nine miles the width gradually diminishes to 800 feet, 500 feet, and 300 feet; and at Las Cascades, where for only seven miles the route

becomes properly speaking a canal, the depth at the normal stage is maintained at 45 feet and the width at bottom at 200 feet. At Pedro Miguel, thirty-two miles from Gatun, a descent of 30 feet is made to a second lake (Sosa) by one duplicate lock. This lake, raised 55 feet above mean tide, is formed by two principal dams, of which the most important one is situated near La Boca, where are also two duplicate locks to conduct to the Pacific. The distance across the lake is five miles, making the total distance between ocean shore lines only forty miles, of which more than three-quarters lie in navigable lakes.

As intimated above, six locks are required, three at Gatun to reach the great lake; one at Pedro Miguel, to descend to Lake Sosa; and two at La Boca to reach Panama Bay. Their dimensions, required by the law of Congress to accommodate vessels "of the largest tonnage and the greatest draft now in use, and such as may be reasonably anticipated," are, subject to revision, to be 1,000 feet long, 100 feet wide, and 40 feet deep. These dimensions under the law much exceed what was previously considered to be necessary to meet the probable needs of commerce for at least half a century. Thus the Comité Technique proposed 738 feet, 82 feet, and 32.8 feet; and the Isthmian Canal Commission of 1899-01 recommended 740 feet, 84 feet and 35 feet. Numerous borings and repeated investigations have demonstrated that all of the locks, of the dimensions now proposed, will rest upon rock of such character that it will furnish a safe and stable foundation, and there is no reason to apprehend difficulties or dangers in the passage of shipping. Practical experience with large locks, large ships, and an immense traffic on our great St. Mary's waterway, which carries annually, although blocked by ice in the winter, more tonnage than all four of the other most important ship canals of the world taken together, is conclusive as to safety of passage. With substantial piers of approach, and suitable guard gates, and by moving the vessels by stationary power other than their own, dangers to locks and to shipping in transit are as nothing compared to those frequently encountered by the latter on the ocean.

Gross misrepresentation, largely from interested parties and enemies of the canal, has been rife in the public press concerning the dam at Gatun. This construction is neither more nor less than a large engineering work involving no problems which may not be

solved by ordinary methods of procedure. The cross section has been slightly changed, and the upstream slope is to be more gradual than originally proposed. It is a technical matter which the public may safely leave to the engineers in charge. The same may be said of the Pacific dams, which are of much smaller dimensions than the one at Gatun.

It remains to consider how the vagaries of the Chagres and the question of water supply in the dry season are treated in the adopted project. In this connection an important and gratifying discovery has been made since the plan was adopted. The earlier projects had contemplated a dam on the river at Bohio, and detailed contoured surveys below that point were lacking. When the Board of Consulting Engineers decided upon a lower location there was no time to make such surveys before adjournment. Consequently the estimate of the area to be submerged by the dam at Gatun at normal lake level had to be formed from the best maps available; and it was taken at 110 square miles, care being given to avoid any over-valuation, since such would tend to exaggerate the capacity of the lake for absorbing the floods and for storing the reserves. A recent contoured survey has shown the true area at 85 feet elevation, to be 165 square miles; and it is not without interest to see how the change affects the anticipations of the Board.

Beside affording a wide and unobstructed route for shipping in transit, the lake will have two important duties: to absorb in part the excess of volume in floods, and to store the reserves for the three months of deficient river flow. The first requirement was estimated at a rise of two feet above normal lake level; and the second was fixed at a subsidence of three feet, in order to maintain a navigable channel without excessive height in lock walls and lock gates, or unnecessary excavation in shallow parts of the lake. The total oscillation from the normal level of 85 feet above tide was thus restricted to 5 feet. The corresponding figure for the lake projected above Bohio was, in the project of the Comité Technique, 5.7 feet, and in that of the Isthmian Canal Commission of 1899-01, 10.4 feet. Naturally the less the oscillation the simpler will be the problems at the locks. The larger lake is a great advantage, permitting any available funds to be devoted to widening rather than to deepening the navigable channels. This matter will bear a little study.

The rise in floods will depend upon the area of the lake and

the permissible rate of outflow. Since the latter is independent of the area of the lake, and the estimated area is now known to be increased 50 per cent, the computed oscillation for flood regulation is reduced to a little over one foot instead of two, the rate of outflow remaining unchanged. This gain, however, is apparent rather than real since the contemplated encroachment, at the end of the rainy season, of one foot on the two feet, with a view to increase the volume available for low water reserves, would no longer be judicious, especially as the largest floods always occur in November and December.

The correction to be made for storage oscillation is not so simple. Three elements are affected: surface area, loss by evaporation and loss by infiltration. The first of these losses is dependent not only on lake area but also on the rate of evaporation; and both area and rate have been affected by new measurements since the report of the Board was submitted. Since no local observations as to evaporation from exposed water surfaces were then available, the rate assumed (0.24 inch per twenty-four hours) was intentionally liberal. This estimation was based on records kept on Lake Nicaragua, with allowance for the "uncertain data as to lake area below Bohio." Actual measurements have recently been made by Mr. Arango on a reservoir at Bas Obispo, giving average monthly losses per twenty-four hours since December 1, 1906, of 0.135 inch, 0.167 inch, 0.181 inch, 0.212 inch, 0.216 inch, 0.151 inch, 0.104 inch, 0.102 inch, 0.116 inch, 0.112 inch, 0.095 inch, and 0.120 inch. The true local values per day are thus 0.20 inch in the three deficient months, 0.12 inch in the rainy months, and 0.14 inch annually. These figures are consistent with the Lake Nicaragua observations (0.19 inch annually), since the annual rainfall in the basin of that lake is about 65 inches, to compare with about 90 inches at Bas Obispo; and the humidity there should be somewhat less and the evaporation somewhat larger. The Board's estimate of the loss by evaporation in the three deficient months was measured by a flow during that period of 710 cubic feet per second. By the correction of the rate this is reduced to 592 feet-seconds for a lake of 110 square miles, which is raised by the increase in area to 888 feet-seconds.

Any estimate of loss by infiltration must at best be based on suppositions. It has been stated above that the Chagres is largely

fed by ground water at all seasons, except at the very end of the three dry months; a fact which is inconsistent with serious loss by seepage or escape by subterranean flow. The Board's estimate is represented by a flow of 77 feet-seconds. Since such losses in this valley must be restricted to a few points of escape, it is conservative to assume that adding fifty per cent to the lake surface will not more than double this loss, raising it to 154 feet-seconds. The aggregate of the two losses is thus raised from 787 feet-seconds to 1,042 feet-seconds, an increase of about 33 per cent. To this must be added the Board's estimates for leakage at gates, 250 feet-seconds; for lighting, power, etc., 200 feet-seconds; and, finally, for contingencies, 200 feet-seconds, making a grand total of 1,692 feet-seconds to cover all losses in the dry season other than those for lockage. This total deducted from that contributed by the stream itself in the three deficient months, joined to the volume three feet deep stored in the lake below elevation 85, will represent the volume available for passing vessels through the locks.

The *minimum* flow of the stream at Gatun during the ninety days of deficient flow was estimated by the Board at 1,250 feet-seconds (the average being 2,360); this was based on ample data available at Bohio, and upon over one hundred gaugings of the Isthmian Canal Commission of 1899-01, on the tributaries below that point, including an exceptionally dry year. Ignoring the insignificant reduction of lake surface produced by a subsidence of 3 feet, the storage volume above elevation 82 feet is represented by 13,800 million cubic feet instead of 9,198 million figured upon the old area. Adding these two sources of supply and deducting the losses (1,692 feet-seconds) indicated above, there will remain available for lockage a revised volume of 10,360 million cubic feet. How many transits will this permit in the ninety days of deficient flow?

The following lockage estimates are based on the dimensions now proposed, namely, with a depth of 40 feet, a usable length of 1,000 feet and a width of 100 feet, both of the latter dimensions exceeding those favored by the members advocating a lock canal, who in the text of their report used smaller figures (40 x 900 x 95 feet). To save needless waste of water, and what is even more important, *needless time in lockage*, interior gates were admitted on the Pacific slope, affording a usable length of 550 feet, but not

on the Atlantic slope, by reason of the three locks in flight; and in traffic computations it was assumed that eight-tenths of the vessels would use the smaller chambers. Upon these suppositions the volume now to be expended for one daily transit of the canal would be, if using only the large chambers, 71.2 feet-seconds, and if using both on the Pacific slope only, 58.2 feet-seconds. Making the computation with these values, and comparing the results with the old figures, the gain resulting from the new data over that available to the Board is, using only the large chambers, 18.7 daily transits to compare with 13.7; and using both chambers as indicated above, 22.9, as compared with 17.1. The project is thus rendered more attractive than was supposed before the discovery that a larger lake area is available; but if desired the showing may be still further improved by introducing the system of intermediate gates in the triple flight of locks at Gatun, placing the small chambers at the down-stream ends of the upper and middle locks and at the up-stream end of the lower lock. By proper operation of the intermediate gate in the middle lock this location virtually reduces the flight of three locks to a single lock separated from a flight of two by a pseudo-canal about 465 feet long. The manœuvres at a transit will be the following:

Suppose the last ship had ascended by the large chambers, leaving them all full; a ship descending by the small chambers after moving into the middle lock will close the middle gate behind it before descending into the lower lock, thus leaving the little pseudo-canal full. It will remain full, no matter how many ascents and descents be made by the small chambers, provided only that the gates be manipulated properly. If, on the other hand, the last ship using the large chambers had descended, leaving them all empty, the first ship to make use of the small chambers will draw from the summit level a full large chamber lockage with which not only to pass but also to permanently fill the pseudo-canal about 465 feet long. This small extra expenditure occurring but rarely, need not be considered in the computations, being much more than covered by the allowance of 200 feet-seconds for contingencies. Adopting this system at Gatun as well as upon the Pacific slope, the lockage volume for one daily transit of the canal, using small and large chambers in the ratio of eight to two, will be 46.3, to compare with 58.2 feet-seconds, when only the Pacific slope is equipped

with intermediate gates. This will further increase the number of daily transit during the dry season to 28.7, to compare with 22.9 when large chambers only are used in the Gatun flight, and to compare with 18.7 without small chambers on either slope.

But it must be noted that these figures by no means limit the possible traffic. It will be easy when more is demanded to store from surplus flow in the rainy season a large reserve in an upper lake formed by the dam projected at Alhajuela (capacity 11,300 million cubic feet, estimated cost $2,400,000), supplemented, if needful, by others on the Trinidad and Gatuncillo. This available volume is represented by the *minimum* annual flow of the Chagres at Gatun, 5,730 feet-seconds as adopted by the Board upon trustworthy records covering fourteen years, the corresponding average flow being 8,173 feet-seconds. In making the computation, losses by evaporation and infiltration in the upper lake must be included, its area being 13.5 square miles. The recently measured rate of annual loss by evaporation (0.14 inch per twenty-four hours) is applied to both lakes; the loss by infiltration in the upper is placed at 10 feet-seconds, proportioned to its area; the other figures above remain unchanged. Such a computation will show that the water supply is ample to permit annually 59.3 daily lockages, using the large chambers only; 72.7 using the smaller as proposed on the Pacific slope; or 91.2 using them on both slopes. These figures demonstrate that the Chagres will meet all possible needs of the canal, and that the only limit to traffic is fixed by mechanical delays in passing ships. The Board with intermediate gates on the Pacific slope figured on twenty-six daily transits, corresponding to an annual traffic of about forty million tons, but this might be increased at any time by adding new locks.

In fine, the adopted project offers easy lake navigation for about three-quarters of the entire distance between the oceans, and meets all the prospective needs of commerce. The delays in passage inherent to a restricted route will be limited to the deep cut at the Culebra, only about seven miles in length, and if desired the entire transit can be made in a single day without encroaching on the hours of darkness. Such advantages as compared with the conditions of any economically practicable route at sea level are cheaply purchased by the passage of a few modern locks.

Present Organization on the Isthmus.

The spring of 1907 may properly be regarded as the end of the preparatory period, inasmuch as the technical plan of the canal or even whether it should be of sea level or lock type, had only been decided by Congress and approved by the President in the preceding June. At this date the status of the work was highly satisfactory. The chief engineer, Mr. John F. Stevens, had created an efficient organization, comprising a working force on the canal and railroad of about 25,000 men, well lodged and fed, with a good supply of modern plant; Colonel Gorgas had accomplished wonders in the sanitation of the Isthmus; and cordial relations had long been established with the government of the republic. The time had come when the work of construction could be pushed judiciously. The President considered that under these conditions the Commission should move its headquarters to the Canal Zone, and as both Mr. Shonts and Mr Stevens had tendered their resignations he radically reorganized this Commission. When Senator Spooner drafted the bill which ultimately became the law authorizing the purchase of the concessions and property of the New Canal Company, he provided that the work should be executed under the War Department, the intention being that the immediate direction should be vested in the Corps of Engineers of the Army, upon which such duties in this country usually devolve; but in the discussion before the Senate this provision was changed, and an Isthmian Canal Commission of seven members was substituted. The present Commission, fourth of the name, combines the two ideas. Its personnel is thus constituted under the immediate direction of the Secretary of War, Judge Taft:

Lieutenant-Colonel George W. Goethals, Corps of Engineers, Chairman.

Major David DuB. Gaillard, Corps of Engineers.

Major William L. Sibert, Corps of Engineers.

Rear Admiral H. H. Rousseau, Civil Engineer, U. S. Navy.

Hon. Joseph C. S. Blackburn.

Colonel William C. Gorgas, Medical Dept. U. S. Army.

Mr. Jackson Smith.

Colonel Goethals, who is also chief engineer, has general charge and direction of construction and engineering. Major Gaillard has special charge of the department of excavation and dredg-

ing. Major Sibert, of the department of lock and dam construction, also including the division of meteorology and river hydraulics. Admiral Rousseau, of the department of municipal engineering, motive power and machinery, and building construction. Mr. Blackburn, of civil administration; Colonel Gorgas, of sanitation; Mr. Smith, of labor, quarters and subsistence. Mr. Joseph Bucklin Bishop is secretary of the Commission.

Since this last reorganization, which dates from April 1, 1907, the detail of officers of the Corps of Engineers for duty on the Isthmus has been resumed. On August 1, Major Edgar Jadwin was assigned to the department of excavation and dredging, as division engineer of the Chagres division; and on the same day Major Chester Harding was assigned to the department of lock and dam construction, as division engineer of the Gatun division. On October 16 Captain Horton W. Stickle, and on November 12 Captain George M. Hoffman, were detailed for like duty. These two departments, upon which devolves all work of canal construction proper, are divided locally into nine divisions under the two commissioners in charge.

On July 1, by direction of the President, the duty of purchasing engineering materials and supplies for the Commission was placed under the supervision of the Chief of Engineers of the Army. By his order Major Harry F. Hodges was assigned to this duty on August 15, and officers and agents of the department were directed to make such purchases, inspections and shipments in the vicinity of their several offices as he may request in the name of the Chief, and to render duly authenticated vouchers to him for payment. Under this plan the force at the Washington office of the Commission is largely reduced, and in procuring the needed supplies advantage is taken of existing agencies widely distributed over the United States. The system of accounting is also simplified; the papers now go direct to the Auditor of the War Department, instead of passing to him through an intermediate auditor of the Isthmian Canal Commission.

On March 22, 1907, a new code of civil procedure was ordered by the President to take effect within the Zone on May 1. The chief justice of the supreme court is Dr. F. Mutis Durán, and the two associate justices are Messrs. H. A. Gudger and Lorin C. Collins.

The importance of continuing the French system of river and climatological records is appreciated. The work, assigned to the supervision of Major Sibert, remains organized as a division under Mr. Ricardo M. Arango, who has been in charge since it was created in June, 1905. The fluviograph records with occasional gaugings are continued at Alhajuela, Gamboa and Bohio; and quite recently measures have been taken to determine the contributions of the two important tributaries below Bohio, the Trinidad and Gatuncillo, checked by fluviograph records and gaugings near Gatun. The deficient slope in the lower Chagres at low stages, and the tidal changes of level, although fortunately moderate in the Caribbean Sea, make the determination of discharge at Gatun at such times a delicate one—as has always been the case at Bohio, but to a much less degree. Arrangements have recently been made to put the system of river gaugings to practical use in excavation by sending warnings, twenty-four hours in advance, of interruptions to be expected from freshets or floods coming from the upper river.

Regular observations upon evaporation were inaugurated in December, 1906, at Bas Obispo, supplemented by wind records both as to velocity and direction. An old masonry pool or tank fully exposed to sun and wind was utilized for this purpose, thus making sure that the results will not suggest underestimates of loss in the reserves stored in the prospective lakes. The records to date have been given above.

Two new seismographs of latest type have been ordered recently to replace the original French instruments, in use at Ancon since September, 1900. One will be placed at a position where it will be exposed as little as possible to earth tremors caused by blasting, and the other at a central location to be used in studying the rate and laws of transmission of such earth waves.

To continue the local rain records, which in this district of heavy downfall have practical importance in connection with current works of excavation as well as with studies for river regulation, twelve stations along the line of the canal are now equipped with rain gauges of approved patterns.

In addition, four complete meteorological observatories, provided with instruments like those in use at weather bureau stations in the United States, have been established at Naos, Ancon, Bas Obispo and Cristobal. Here regular observations are made of

temperature, barometric pressure, relative humidity, and clouds, together with any special phenomena. At the coast stations tidal records and water temperature are added. In brief, provisions for continuing and extending the scope of the elaborate French observations have received attention.

Potable water is now furnished from four main storage reservoirs,—the Mount Hope near Colon, the Rio Grande for the Pacific slope, the Camacho and the Gatuncillo for the interior,—together with auxiliary pumping stations supplied by them and by dams on the Caribali and Frijoles rivers.

Progress in Work of Construction.

Between the transfer of the property to the United States on May 4, 1904, and April 1, 1907, in other words during the period of the first two Commissions charged with works of construction, there has been removed, measured in place and at a cost for steam shovel work of about 78 cents per cubic yard:

	Cubic Yds.
At Culebra Cut, by steam shovels:	
In 1904	243,472
In 1905	914,254
In 1906	2,702,991
In 1907, to April	2,021,132
Total	5,881,849
At Gatun, by steam shovels, beginning October, 1906	244,495
At La Boca, by steam shovels, beginning March, 1907	3,905
Total steam shovel work	6,130,249
At Colon, outside canal prism, by dredges	1,732,712
At La Boca, outside canal prism, by dredges	1,956,895
Total by dredges	3,689,607
Grand total excavation	9,819,856

The total estimated excavation remaining on April 1, 1907, to complete the canal, including both steam shovel work and dredging, was:

	Cubic Yds.
Canal prism	101,050,000
Lock sites	7,965,000
Regulating works and diversion channel	2,150,000
Construction channels, Cristobal and Panama	3,350,000
Total	114,515,000

This estimate includes 500,000 cubic yards to completely remove all threatening material at the old Cucaracha slide, which caused the most annoyance in the days of the de Lesseps Company. It lies on the east side of the cut about half a mile from Gold Hill, and to the southward from the deepest part of the excavation. In October, under the heavy rains, an earth movement toward the cut began at a rate of about fourteen feet per day, and three steam shovels were put to work night and day to hold it in check; this soon produced the desired effect.

On July 1, 1907, there were in service on the Isthmus 63 steam shovels, of which 3 were of the 45-ton type, 28 of the 70-ton type with 2.5-yard buckets; and 32 of the 95-ton type, the latter equipped with 5-yard buckets and capable of handling a rock of over ten tons in weight; thirty-seven shovels were under contract. Their chief duty has been and will be at the Culebra division, where the distance of the dumps reduces the output. Thus in this month 132 locomotives were at work there on over 106 miles of track; and the aggregate length of holes drilled for blasting was 19.38 miles. In September this length was 20.5 miles, and 107 tons of explosives were used. On September 17, when 39 shovels were at work, the daily average (eight hours) was 875 cubic yards. On the same day four shovels at the Gatun lock site average 1,305 cubic yards each. These were record outputs. A single shovel in eight hours has registered at Bas Obispo 1,954 yards; at Culebra, 2,188 yards, and at Pedro Miguel, 3,040 yards. This was in November.

The question of labor has presented a different phase since the American occupation. Under the old sanitary conditions experience demonstrated that dependence must be placed upon the negroes of the West Indies, as it appeared that they alone could perform hard labor safely under the tropical sun. Their labor was of a very inferior character, and under the new sanitary conditions it has been found that Spanish, Italian and Greek laborers are not only much superior but also show a less death rate. Over 5,000 of them were employed in November. The negroes suffer much from pneumonia, from which the whites are exempt, or nearly so. At the end of October 25,915 men were working on the canal and 6,139 on the Panama Railroad, the aggregate rolls showing a much larger number. The idea of completing the work by contract, although seriously entertained prior to the appointment of the present Commission, seems now to be definitely abandoned.

Work on the canal is divided locally between two divisions, forming the Atlantic and Pacific approaches, the Culebra division including the cut through the continental divide, the Chagres division extending thence to deep water in Gatun Lake, and the Gatun division including the dam and locks. Each will be considered in turn.

At both of the ocean approaches considerable dredging will be necessary. The Colon division extends from the Gatun locks to Mindi and thence to deep water in the Caribbean Sea; here some 21,000,000 cubic yards are to be removed, of which about 3.7 millions are rock. One 16-inch suction dredge, two 5-yard dipper dredges, and one French ladder dredge are at work, and a second French ladder dredge is undergoing repairs for this purpose. They are served by four French self-propelling hopper barges, known as "Clapets," and one tug, together with six new steel hopper barges requiring to be towed by the others.

The La Boca division extends from the locks at Pedro Miguel to deep water in Panama Bay; and here some 15,000,000 cubic yards are to be removed, of which about one-twentieth is rock. The dredging plant now here consists of two French ladder dredges and one 5-yard dipper dredge served by eight "Clapets;" three steel hopper barges to be towed by the latter are under contract. The old French material has been repaired and is reported as doing excellent service; two of the ladder dredges removed 287,107 cubic yards during October. The new sea-going suction dredge "Culebra" is expected to arrive from Baltimore, via the Straits of Magellan, in January, 1908—a voyage of 12,000 miles. Its consort, "Ancon," which will work pumping material on the Gatun dam when the site has been prepared, has made a fine record in Limon Bay, where it arrived in last August. In September it removed and dumped in the sea off Toro Point 260,773 cubic yards, a volume equivalent to the output of 14 steam shovels served by about 30 trains of 16 cars each; thus 57 men operating the dredge did the work of about 1,500—but working of course in much softer material.

The heaviest excavation is concentrated in the Culebra division between Bas Obispo and Pedro Miguel, a distance of nine and a half miles. This is now organized in five sections of about equal length, each under a local superintendent, reporting through two intermediate engineers to the commissioner in charge, Major Gail-

lard. Throughout this distance a 10-inch pipe line main has been extended, with 6-inch and 4-inch leads running into the canal prism. Air pressure is maintained by twelve compressors, each having a capacity of 2,500 cubic feet per minute, at 100 pounds pressure, all feeding into the main. This supplies power to the rock drills and stone crushers on the line, and to the coal chutes, and to the machine shops at Las Cascadas and Pedro Miguel. A recent invention of Mr. Bierd, late manager of the Panama Railroad, has introduced an improvement in the mode of transferring the soil to the dumps. Under the heavy rainfall during nine months of the year the constant shifting of track incident to the work has always caused much loss of time. Instead of the old operation of prying up the rails with screw jacks, shifting the ties, and then spiking the track down again, the device of Mr. Bierd shifts the whole at once. It consists of a double-drum hoisting engine with a horizontal and a vertical boom, all mounted on a flat car. It is capable of throwing 5,400 lineal feet of track a distance of 9 feet in eight hours, representing the work of five or six hundred men under the former system. It is operated by three mechanics and six laborers. As this kind of work never ceases, the saving both of time and cost is important. The use of mechanical unloaders also greatly expedites work. A record is reported when a single unloader served by 28 white men and 43 laborers and firemen disposed in eight hours of the material, 5,000 cubic yards, brought by 16 trains.

The Chagres division, so-called, extends from the point where the river first strikes the canal to deep water in Gatun Lake. Here the excavation will approximate to 13,000,000 cubic yards, of which about 5,000,000 are rock. The width of the channel for shipping gradually widens as the deep lake is approached, and crosses the present bed of the river over twenty times. In the northern portion the latter will not require excavation, but the banks throughout form detached peninsulas which must be removed. The rock and earth nearby will be excavated with steam shovels, and the remaining earth will be dredged after the lake begins to rise. Work has been started at three points already. It is here that freshets will cause most annoyance. The old French diversion channels to the southward have been considerably extended, and more work of this kind is in progress.

The following figures show the monthly progress in excava-

tion since the last reorganization of the Canal Commission. At the Culebra in September about five-sevenths of the output were classed as rock.

Output in Cubic Yards in 1907.

Month.	By Steam Shovels.					By Dredges near		Total.
	Culebra.	Gatun.	Mindi.	Chagres.	La Boca.	Colon.	La Boca.	
April	879,527	103,459	.....	.....	1,756	69,889	104,855	1,159,486
May	690,365	70,528	.....	.....	762	133,847	122,157	1,017,659
June	624,586	75,013	.....	.....	4,907	124,118	131,580	960,204
July	770,570	74,165	731	.....	13,772	109,922	108,338	1,077,498
August	786,866	105,223	15,257	2,820	15,865	209,554	168,284	1,303,869
September	753,468	123,738	28,837	23,746	12,806	420,842	161,350	1,524,787
October	834,499	177,013	41,078	25,627	7,108	426,282	357,122	1,868,729
November	790,632	162,622	40,003	44,044	8,190	427,572	365,423	1,838,486
Total	6,130,513	891,761	125,906	96,237	65,166	1,922,026	1,519,109	10,750,718

Before the type of the canal was decided (June, 1906) it was impossible to begin work on the locks and dams,—an unfortunate circumstance, because here will now probably be found the chief delays in opening the route to traffic. Operations under the supervision of Major Sibert have, however, started vigorously at Gatun. At the end of August, six steam shovels were excavating at the lock sites and spillway, and railway trestles were erecting and preparations were making for dumping and sluicing materials at the dam. So soon as the pipe line dredges and the plant for mixing concrete can be installed progress will be rapid. Suitable stone and sand for concrete have been located near Porto Bello; also material for cement of the highest grade at a cost not exceding $1.34 per barrel, in case unreasonable prices should be demanded for supplying it by sea. To reduce expense the idea has been suggested of importing cement clinker to be ground on the Isthmus. Work on the lock and dam sites at La Boca has also been inaugurated actively.

The Panama Railroad is in busy operation. During last June, in addition to the 1,284 commercial trains, 3,874 construction trains were reported as transporting canal materials. As many as 196 trains occasionally passed a single point on a single day. The wear and tear of the hard service upon the cars, loaded often with huge rocks by steam shovels and discharged mechanically at the dumps, demands continual repairs, and the shops at Gorgona,

Empire, and Paraiso are under constant pressure. In June work was begun simultaneously at seven different points on the new permanent location of the railroad; about 10,000,000 cubic yards of fill in excess of excavation will furnish dumps for material from the canal prism, as the lake will cause important changes in the line.

But, it may be asked, how about finances? The total outlay needful for opening a governmental route for shipping between the Atlantic and Pacific Oceans, via the Isthmus, is naturally classed under two distinct categories—the technical cost of constructing the canal, and certain collateral expenses of ownership and control, such as for right of way, for Zone government, for sanitation, including that of the cities of Panama and Colon, to be repaid ultimately, and for the commercial operation of the Panama Railroad. These several items are often improperly blended in one, and the daily press is already beginning to claim that nearly the whole of the estimated cost of constructing the canal has been expended already. The truth will be understood from the following statement.

The total expenditures which are properly chargeable to technical canal construction are shown in the following table, based on official statements in the *Canal Record*:

	To Dec. 31, 1906.	To June 30, 1907.
For material and supplies	$3,449,022.96	$3,649,665.13
For general administration	1,124,226.55	1,403,557.68
For construction and engineering	9,729,554.98	15,594,834.17
For plant	12,138,852.17	18,484,300.74
Total since transfer	$26,441,656.66	39,132,357.72

The aggregate outlay for all expenditures, including right of way, during these two periods was respectively $84,449,000.32 and $98,285,110.37. The gross error of charging aggregate outlay to canal construction proper is thus apparent. The question remains, what is the proper standard for judging whether or not the actual work of construction is progressing in a satisfactory manner from a financial point of view.

In the act approved June 29, 1906, Congress specifically indorsed the project submitted by the members of the Board of Consulting Engineers favoring the lock type of canal, for which the

estimate was $139,705,200. This estimate includes no part of the outlay (approximately $16,000,000) prior to the rendition of their report (January 10, 1906), and expressly excludes all future costs of sanitation and of the Zone government. Furthermore, the unit prices were based on a 10-hour day, which had always ruled on the Isthmus, and to which the adoption of an 8-hour day has added 20 per cent in so far as the cost of labor is involved. Thus it appears that, even omitting this last increment of the estimate, only about $10,000,000 should be considered as expended upon the adopted project on December 31, 1906, and only about $23,000,000 on June 30, 1907. In other words, at the latter date there remained of it unexpended about $117,000,000. Wage rates ruling higher than those under the direction of the private French companies, and much larger and more expensive locks than were contemplated by the project as submitted, may enhance the estimated cost; but there is no indication that there will be a serious deficit.

In fine, an era of rapid progress has been inaugurated under an efficient organization, with every promise of success, and the expenditures have been kept within reasonable limits. It would still be premature to predict any exact date of completion, but there is no reason to apprehend needless or long delay. The estimate of the Consulting Engineers reporting the project (but with locks of smaller dimensions) was nine years, dating from the beginning of active prosecution of the work. Nearly one year of the nine has already passed, and any reduction of this estimate will reflect credit on the canal administration.

NOTE.—The important announcement has just been made that the President, upon the recommendation of Colonel Goethals, has approved a radical change in the plan of the canal near the Pacific coast, by suppressing the projected Lake Sosa and transferring the two locks in flight from La Boca to Miraflores, thus locating the latter about four miles inland and connecting them with the ocean by a channel at sea level about 500 feet wide. This was the disposition adopted by the engineers of the New Panama Canal Company, and it is decidedly an improvement, since it not only largely reduces the cost but also places the locks in a position much less exposed to bombardment by a hostile fleet. Numerous test pits at Miraflores demonstrate that solid rock foundations exist for the locks at that locality, and the construction of two large dams becomes unnecessary.